Case Study

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The effect of complex rehabilitation training for 12 weeks on trunk muscle function and spine deformation of patients with SCI

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Abstract. [Purpose] It is important for patients with incomplete spinal cord injury (SCI) to strengthen their muscle strength and return to the work force one of the ultimate objectives of rehabilitation. This study reports how a single patient with SCI became stabilized in terms of abdominal muscles and back extension muscles, as well as returning the back to the neutral position from spinal deformation, as result of complex exercises performed for 12 weeks. [Subjects] The degree of damage of the subject was rated as C grade. The subject of this study had unstable posture due to paralysis in the lower extremities of the left side after removal of a malignant tumor by surgical operation, and tilting and torsion in the pelvis increased followed by increase of kyphosis in the thoracolumbar spine. The subject was more than two years since diagnosis of incomplete SCI after surgery. [Methods] Using isokinetic lumbar muscle strength measurement equipment, peak torque/weight, total work and average power in flexion and extension of the lumbar region were measured. A trunk measurement system (Formetric 4D, DIERS, Germany), which is a 3D image processing apparatus with high resolution for vertebrae, was used in order to measure 3D vertebrae and pelvis deformation as well as static balance abilities. As an exercise method, a foam roller was used to conduct fascia relaxation massage for warming-up, and postural kyphosis was changed into postural lordosis by lat pull-down using equipment, performed in 5 sets of 15 times preset at 60% intensity of 1RM 4 set of 10 crunch exercises per set using Togu's were done while sitting at the end of Balance pad, and 4 sets of 15 bridge exercises. [Results] All angular speed tests showed a gradual increase in muscle strength. Flexion and extension showed 10% and 3% improvements, respectively. The spine deformation test showed that isokinetic exercise and lat pull-down exercise for 12 weeks resulted in improved spinal shape. [Conclusion] In this study, core stability exercise for deep muscle training and lat pull-down exercise had positive effects on lower extremity muscle strength and the spinal shape of a patient with SCI.

Key words: Spinal Cord Injury (SCI), Stability, Lat pull down

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INTRODUCTION

Disabilities related to spinal cord injury vary according to the degree of damage, and the damaged spinal segments or nerve fibers. General symptoms after spinal cord injury are functional loss due to damage of motor and sensory nerve fibers, disorders of urination, defecation, and sexual function as well as other complications such as bed sores, urinary tract infection, stiffness, joint contracture, reduction of breathing ability, digestive disorder, pain, and autonomic disturbance[1)]. An incomplete spinal cord injury refers to cases where some motor or sensory nerve fibers are preserved after partial spinal cord injury, and some of nervous systems pass intact through the damaged area to the distal spinal cord segments[2)]. Even if partial muscle innervation remains, weakening of the trunk muscles and reduction of somatosensory sense in the damaged cord area occur making maintaining balance difficult[3)]. Rehabilitation and return to society are the most important goals of patients with spinal cord injury. The WHO also emphasized this in a report called International Classification of Functioning, Disability and Health[4)]. Since physical structure, functions, and activities of patients with SCI are closely related, clinicians should select appropriate therapy strategies to improve patients' physical abilities[5)]. Forssberg[6)] reports the major conditions of successful gait for patients with SCI are: the trunk should be balanced, with two lower extremities and driving force of the body moving in the intended direction, and dynamic balance for control of the body as well as the ability to flexibly change movement according to environmental requirements and aims.

Patients with SCI use non-paralyzed muscles in order to

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Table 1. Exercise program

List		Content	Rep	Set
Warm up		Fascial release massage	10 min	
	Resistance exercise	Lat pull down	15	5
		Crunch	10	4
Main exercise	Core stability exercise	Bridge	15	4
		Cross arm leg lift	20 sec	5
	Isokinetic exercise	Isomed 2000 (180°/sec)	30	5
Cool down		Stretching exercise	10 min	

maintain sitting posture due to weakening or paralysis of the trunk muscles and sensory reduction in the damaged area[7]. This causes straight neck, kyphosis in the thoracolumbar spine, and pelvic posterior tilt in the pelvis[8]. In this study, when malignant tumors were removed from 12th thoracic vertebra and 1st and 2nd lumbar vertebrae, paralysis of the left leg and kyphosis of the thoracolumbar spine increased creating an unstable posture and rapid decrease of muscle strength in the lower extremities. It is important for patients with incomplete SCI to strengthen their muscle strength and return to the workforce, which is one of the ultimate objectives of rehabilitation. Thus, this study reports how a single patient with SCI became stabilized in terms of abdominal muscles and back extension muscles, as well as returning the back to the neutral position from spinal deformation, as a results of complex exercises performed for 12 weeks.

SUBJECTS AND METHODS

The subject of this study had unstable posture due to paralysis in the lower extremities of the left side after the removal of malignant tumors by surgical operation, and tilting and torsion in the pelvis increased followed by increase of kyphosis in the thoracolumbar spine. The subject was more than two years since diagnosis of incomplete SCI after the surgery. The subject had gait training for two years so he could walk independently and stand from the sitting position, but the left leg still experienced circumduction. The subject was 22 years old, 175.6 cm in height, and 78.6 kg in weight.

The degree of damage of the spinal injury was rated as C grade. The American Spinal Injury Association (ASIA) defines the functional level of spinal injury based on more than grade 3 level is found. The ASIA injury scale (modified from Frankel) is the most widely used for the classification of spinal cord injuries, and it shows the spinal cord injury degree qualitatively (America Spinal Cord Injury, 2000). The spinal cord motor index is a qualitative scale describing the motor ability of patients.

The subject understood the purpose of this study and provided his written informed consent prior to his participation in the study in accordance with the ethical principles of the Declaration of Helsinki.

Using isokinetic lumbar muscle strength measurement equipment (Isomed 2000, Back system, Germany), peak torque/weight, total work and average power in flexion and extension of the lumbar region were measured.

A trunk measurement system (Formetric 4D, DIERS, Germany), a 3D image processing apparatus with high resolution for vertebrae which was used in the studies of Lippold, Danesh, Schilgen, Drerup & Hackenberg[9] and Schroder[10], was used in order to measure 3D vertebrae and pelvis deformation as well as static balance ability.

As an exercise method, a foam roller was used to conduct fascia relaxation massage for warming-up, and postural kyphosis was changed into postural lordosis by lat pull-down exercise using equipment, performed in 5 sets of 15 times at 60% intensity of 1RM, 4 set of 10 crunch exercises using a Togu were done while sitting at the end of a Balance pad, and 4 sets of 15 bridge exercises. Finally, 5 sets of cross arm leg lifts were conducted for 20 seconds, and 5 sets of 30 trunk flexions and extensions were done at the angular speed of 180 degrees using an ISOMED-2000 for isokinetic exercise. For cool-down, simple stretching was done. The detailed contents of the exercise program are shown in Table 1.

RESULTS

Table 2 shows the results of isokinetic muscle function tests and lat pull-down exercises for 12 weeks. All the angular speed tests show a gradual increase of muscle strength. Flexion and extension showed improvements of 10% and 3%, respectively. Average power showed improvements of 40% in flexion and 39% in extension. At angular speed of 60°/sec, peak torque showed improvements of 7% in flexion and extension, while total work showed improvements of 10% in flexion and 13% in extension. Average power showed improvements of 13% in flexion and 16% in extension.

At the angular speed of 120°/sec, peak torque showed improvements of 22% and 17% in flexion and extension, while total work showed improvements of 27% and 9% in flexion and extension, respectively. Average power showed improvements of 50% in flexion and 25% in extension.

The spine deformation test showed that isokinetic exercise and Lat pull-down exercise for 12 weeks have resulted in improved spinal shape. Table 3 shows the improved spinal shape changes.

The kyphosis angle was 57° after performing isokinetic exercise and Lat pull-down exercise for 12 weeks which was close to normal reference angle of 51°, while the lordotis angle was 50°, which was also close to the normal reference angle of 43°.

Table 2. Isokinetic muscle function test

Factor	Measure (Unit)	Pre test	Second test	Post test
30°/Sec	Peak Torque Flex / weight (Nm/kg)	1.2	1.2	1.3
	Peak Torque Ext / weight (Nm/kg)	1.6	1.7	1.7
	Total Work Flex (J)	145	152	159
	Total Work Ext (J)	354	361	365
	Average Power Flex (W)	10	13	14
	Average Power Ext (W)	23	29	32
60°/Sec	Peak Torque Flex / weight (Nm/kg)	1.2	1.2	1.3
	Peak Torque Ext / weight (Nm/kg)	1.6	1.7	1.7
	Total Work Flex (J)	136	140	149
	Total Work Ext (J)	456	478	515
	Average Power Flex (W)	8	9	9
	Average Power Ext (W)	32	36	37
120°/Sec	Peak Torque Flex / weight (Nm/kg)	0.6	0.6	0.7
	Peak Torque Ext / weight (Nm/kg)	1.2	1.4	1.4
	Total Work Flex (J)	132	157	168
	Total Work Ext (J)	332	354	361
	Average Power Flex (W)	8	11	12
	Average Power Ext (W)	24	25	30

Table 3. Spinal deformation results

Curve (Unit)	Pre test	Second test	Post test
Kyphosis angle (°)	67	62	57
Lordosis angle (°)	62	55	50

DISCUSSION

Panjabi[11] reported that lumbar stabilization exercise, a muscle strengthening exercise for the deep muscle group, plays an important role in providing dynamic stabilization in the segments providing lumbar segmental stability, and is useful for decrease in spinal functional disorder. Richardson et al.[12] proposed that lumbar stabilization exercise increased the stability of the spine and pelvis while performing functional postures and movements.

Critchley et al.[13] evaluated the activation of the transversus abdominis muscle in a group of 20 patients with chronic low back pain and a group of 24 normal adults the normal group showed 49.71% of activation while the group of patients with chronic low back pain showed 19.15% of activation, significantly less activation than the normal group. Another study of patients with chronic low back pain showed that both a group segmental stabilization exercise and a group performing segmental stabilization exercise with bio-feedback using ultrasound double the activation of the transversus abdominis muscle[14]. The present study also found improvements in isokinetic low extremity muscle function after performing bridge exercise and leg lifts that strengthen the lower extremity muscles along with lumbar stabilization exercise for back strengthening, a results which is consistent with those of studies cited above.

Both internal oblique and transversus abdominis muscles are deep abdominal muscles, which contribute to lumbar stabilization with specific rules so that damage of motor control system to such muscles causes spinal instability. Furthermore, internal oblique and transversus abdominis muscles are poorly controlled in patients with low back pain[15]. In the present study, lumbar stabilization exercise decreased kyphotisis and lordosis in an SCI patient with kyphosis due to abdominal and low back muscle weakening.

The lat pull-down training for posture correction elicits a significant effect on spinal kyphosis. It is general common sense that exercise can improve muscle strength. A lumbar stabilization exercise is one that strengthens the core muscles, which are deep muscles. It improves internal and external lumbar stabilization through isometric contraction by the muscles of the abdomen. The muscles used for lumbar stabilization are divided into deep stabilizer muscles and superficial stabilizer muscles. The lumbar area can be greatly strengthened when the superficial stabilizer muscles, as a large muscle group, and deep stabilizer muscles, as a local muscles group, are strengthened[16].

Lumbar stabilization exercises can solve the problem of deficiency of motor control in the trunk and instability of postural balance. They are effective at reducing of low back pain, increasing the range of motion of the trunk and pelvis, and improving body balance, neuromuscular control, and muscle strengthening methods[17, 18]. Furthermore, exercises on unstable surfaces make sensory motor training possible[19]. The stabilization exercise used in this study increased muscle strength in the lumbar area thereby improving postural balance and muscle strength in the lower extremity.

Shumway-Cook & Woolacott[20] revealed that muscles pass through body segments generate co-contraction in order to maintain balance against superficial instability while muscle activation increases as instability of the lower extremities increases[21]. In the present study, after a lumbar stabilization exercise was performed according to lower extremity muscle strength of the subject increased in the unstable.

Hodges & Richardson[21] reported that deep muscles and stabilizer muscles such as the internal oblique and transversus abdominis muscles acted more quickly than the other large muscles to contribute to spine stabilization, while Cholewicki & Van Vliet[22] emphasized strengthening of the superficial stabilizer muscles to reduce the movements between injured spinal segments. Furthermore, Standaert, Weinstein, & Rumpeltes[23] proposed that complex exercise methods should be conducted to strengthen both the large and small muscles. In this study, the core stability exercise for deep muscle training and lat pull-down exercise had a positive effect on lower extremity muscle strength and the spinal shape of a patient with SCI. According to the report by Huang et al.[24], chronic low back pain can be improved by a combination of Pelvic floor muscle exercise and the neuromuscular joint facilitation pattern. According to the report by Ju et al.[25], the exercise treatment program for rehabilitation patients after lumbar disc herniation surgery was effective at strengthening lumbar extensor muscles and reducing pain. Therefore, in the present study showed that consistent with the results of the SCI patient trunk muscle strengthening is a leading research through the rehabilitation training.

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